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(54) Electrospray coating process.

(57) An electrostatic coating system for applying very thin coating to a substrate in air at atmospheric pressure comprises a plurality of spaced capillary needles (11) positioned in at least two rows and fed with coating liquid via a reservoir (15). The needles (11) are disposed concentric within holes (13) in an extractor plate (14), a potential is developed between the capillary needles (11) and the extractor plate (14) affording a reduction of the liquid to a mist of highly charged droplets drawn to the substrate by a second electrical field. Insulative layers (64, 66) on the extractor plate provide increased droplet control.

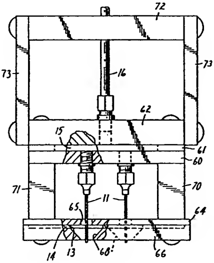

FIG.5

EP 0 258 016 A1

Description

ELECTROSPRAY COATING PROCESS

Technical Field

This invention relates to a device for coating a continuous substrate and in one aspect to an apparatus and method for electrospraying a coating material onto a substrate.

Background Art

A number of substrate coating methods are presently available. Mechanical applications such as roll coating, knife coating and the like are easy and inexpensive in themselves. However, because these methods give thick coatings of typically greater than 5 micrometers (um), there are solvents to be disposed of and this disposal requires large drying ovens and pollution control equipment, thus making the total process expensive and time consuming. These processes are even more awkward for applying very thin coatings, for example, less than 500 Angstroms (Å). To apply such thin coatings by present coating techniques requires very dilute solutions and therefore very large amounts of solvent must be dried off. The uniformity and thickness of the dried final coating is difficult to control.

Physical vapor deposition techniques are useful for applying thin and very thin coatings on substrates. They require high vacuums with the attendant processing problems for a continuous process and are therefore capital intensive. They also can only coat materials that can be sputtered or vapor coated.

The present invention relates to an electrostatic spraying process but it is unlike conventional electrostatic processes which have been used for a number of years. Such processes for example, are used in the painting industry and textile industry where large amounts of material are applied to flat surfaces wherein application of such coatings use a droplet size in the 100 micrometer range with a large distribution of drop sizes. Uniform coatings thus start at about 200 micrometer thickness, which are thick film coating processes. Significant amounts of solvents are required and these solvents do not evaporate in travel from sprayer to substrate so the coating is a solvent wet coating which then requires drying. It is difficult to coat nonconductive substrates with these processes. The spray head design for these electrostatic coating processes usually are noncapillary and designed so that the charged material to be coated comes off a sharp edge or point and forms very large droplets. For example, Ransburg, U.S. patent No. 2,893,894 shows an apparatus for coating paints and the like from an electrostatic spray gun. Probst, U.S. patent No. 3,776,187 teaches electrostatic spraying of carpet backings from a knife edge type apparatus.

Liquid jet generators for ink jet printing are a controlled form of electrostatic spraying. In ink jet generators, streams of drops of liquid on the order of 75 to 125 micrometers in diameter are produced, charged and then guided in single file by electric fields along the drop stream path to the desired destination to form the printed character. Sweet, U.S. patent No. 3,596,275 describes such a generator wherein the series of drops are produced by spaced varicosities in the issuing jet by either mechanical or electrical means. These drops are charged and passed one by one through a pair of electrostatic deflecting electrodes thereby causing the writing to occur on a moving substrate beneath the generator.

Van Heyningen, U.S. patent No. 4,381,342 discloses a method for depositing photographic dyes on film substrates using three such ink jet generators as just described in tandem and causing each different material to be laid down in a controlled non-overlapping matrix.

The design of structures to generate small charged droplets are different from the aforementioned devices for painting and jet printing. Zelany, Physical Review, Vol. 3, p. 69 (1914) used a charged capillary to study the electrical charges on droplets. Darrah, U.S. patent No. 1,958,406, sprayed small charged droplets into ducts and vessels as reactants because he found such droplets to be "in good condition for rapid chemical action".

In an article in Journal of Colloid Science, Vol. 7, p. 616 Vonnegut & Neubauer (1952) there is a teaching of getting drops below 1 micrometer in diameter by using a charged fluid. Newab and Mason, Journal of Colloid Science, Vol. 13, p. 179, (1958) used a charged metal capillary to produce fine drops and collected them in a liquid. Krohn, U.S. patent no. 3,157,819, showed an apparatus for producing charged liquid particles for space vehicles. Pfeifer and Hendricks, AIAA Journal, Vol. 6, p. 496, (1968) studied Krohn's work and used a charged metal capillary and an extractor plate (ground return electrode) to expel fine droplets away from the capillary to obtain a fundamental understanding of the process. Marks, U.S. patent No. 3,503,704 describes such a generator to impart charged particles in a gas stream to control and remove pollutants. Mutoh, et al, Journal of Applied Physics, Vol. 50, p. 3174 (1979) described the disintegration of liquid jets induced by an electrostatic field. Fite, U.S. patent No. 4,209,696, describes a generator to create molecules and ions for further analysis and to produce droplets containing only one molecule or ion for use in a mass spectrometer and also describes the known literature and the concept of the electrospray method as practiced since Zeleny's studies. Mahoney, U.S. patent no. 4,264,641, claimed a method to produce molten metal powder thin films in a vacuum using electrohydrodynamic spraying. Coffee, U.S. patent No. 4,356,528 and U.S. patent No. 4,476,515 describes a process and apparatus for spraying pesticides on field crops and indicates the ideal drop size for this application is between 30 and 200 micrometers.

The prior art does not teach an electrostatic coater for applying coatings 10 to 5000 Å. thick at atmospheric pressure.

The prior art does not teach the use of a coater with a wide electrostatic spray head having a plurality of capillary needles.

Disclosure of Invention

The present Invention provides a noncontacting method and a multi-orifice spray apparatus to accurately and uniformly apply a coating onto a substrate to any desired coating thickness from a few tens of angstroms to a few thousand angstroms at atmospheric pressure and at industrially acceptable process coating speeds. The process is most useful in coating webs, disks, and other flat surfaces although irregular substrates can also be coated.

The electrospray coating head comprises a plurality of capillary needles communicating with a fluid manifold and arranged in two or more staggered rows transverse to the path of the web to be coated. A conductive extractor plate has a plurality of holes positioned to receive the needles coaxially in the holes. The extractor plate and needles are connected to a high voltage electrical source with the plate and needles at opposite polarity to define a potential between the two. A second potential is developed between the needles and the receptor web.

The coating process of the present invention is useful in coating monomers, oligomers and solutions onto a substrate in a uniform coating at a thickness of 10 to 5000 Angstroms at atmospheric pressure in air. The process comprises cleaning a web if necessary, charging the web, advancing the web transversely of at least two rows of capillary needles extending through an extractor plate, pumping the coating material through the needles, developing a high voltage electric field between the needles and the extractor plate to spray the web, and removing the excess charge on the web. A curing step may be necessary, depending on the material. The web can receive a second coating or be rewound.

Brief Description of Drawings

The invention will be described in greater detail with reference to the accompanying drawing wherein:

Figure 1 is a front elevational view showing one embodiment of the dispensing and coating head of this invention;

Figure 2 is a bottom view of the dispensing and coating head;

Figure 3 is a diagrammatic view showing the basic steps in a continuous process utilizing a head constructed according to this invention;

Figure 4 is a diagrammatic view of the electrical circuit for the present invention and a single dispensing needle used to produce an ultra-fine mist of droplets; and

Figure 5 is a vertical partial sectional view of a second embodiment of a coating head according to the present invention.

Detailed Description

The present invention relates to an electrospray process for applying thin and very thin coatings to substrates. As used herein electrospray, also referred to as electrohydrodynamic spray, is a type of electrostatic spray. While electrostatic spray is the use of electric fields to create and act on charged droplets of the material to be coated so as to control said material application, it is normally practiced by applying heavy coatings of material as for example in paint spraying of parts. In the present invention electrospray describes the spraying of very fine droplets from a plurality of spaced capillary needles and directing these droplets by action of a field onto substrates, usually in very thin coating thicknesses.

Thin films and very thin films of selected materials on substrates are useful as primers, low adhesion backsizes, release coatings, lubricants and the like. In many cases only a few monomolecular layers of material are required and the present invention is capable of applying such coatings at thicknesses of a few angstroms to a few thousand angstroms. The concept of this invention is the generation of an ultra-fine mist of material and the controlled application of that mist to a substrate to provide a uniform thin film coating of the material on the substrate.

The coating head, generally designated 10, comprises a plurality of capillary tubes or needles 11 in two parallel rows to produce an even, uniform coating of material on a substrate moved beneath the head 10. A coating head design utilizing 27 such needles to produce a 30.5 cm wide coating on a substrate is shown in Figure 1. The capillary needles 11 have a very small bore of a size in which capillarity takes place but the needles must be large enough in inside diameter so that plugging does not occur for normally clean fluids. The extractor plate holes 13 are large enough to assure arcing does not occur between the plate 14 and the needles 11 but small enough to provide the desired electric field strength necessary to generate the mist of droplets.

The liquid to be electrosprayed is fed into an electrospray manifold 15 from a feeder line 16 which is also attached to a suitable liquid pump (not shown). The line 16 is connected to a tee 17 to direct liquid toward both sides of the manifold 15, and the liquid in manifold 15 is distributed to the array of capillary needles 11. Stainless steel needles with an inside diameter (ID) of 300 micrometers (um) and an outside diameter (OD) of 500 um and length of 2.5 centimeters (cm) have been used. The needles 11 are covered with size 24 Voltex Tubing, an insulative tubing from SPC Technology, Chicago, Illinois, to within 0.8 mm of their tip to restrict buildup of coating material on the needles. The needles 11 have a seat 20 attached to a metal plate 21. The plate 21 is connected to a high voltage supply V_1 through a wire 24. The extractor plate 14 is formed of

aluminum or stainless steel and is insulated from the high voltage plate 21 using ceramic adjustable spacers 25 which position the needles through the holes of the extractor plate 14 with the tips of the capillary needles 11 extending slightly beyond the extractor plate. The bottom planar surface and planar edges of the extractor plate 14 is covered with a 0.2 mm thickness of Scotch Brand® 5481 insulative film pressure sensitive adhesive tape available from Minnesota Mining and Manufacturing Company of St. Paul, Minnesota. The tape is an insulator and prevents build-up of electrospray material on this surface. Alternatively, the bottom of this plate can be covered with other insulating material. The extractor plate 14 is 1.6 mm thick and has 27 1.9 cm ID holes 13 drilled in it and placed 2.2 cm on center. These holes 13 are aligned with one hole concentric with each capillary needle 11. As a result, an electric field E_1 (see Figure 4) produced by a difference in electrical potential between the capillary needle 11 and the extractor plate or electrode 14 has radial symmetry. The electric field E_1 is the primary force field used to electrically stress the liquid at the tip of the capillary opening of needle 11 and can be adjusted by the high voltage supply V_1 or by adjusting screws in spacers 25 to change the relative distance between the tips of the needles 11 and the extractor electrode 14. The substrate 30 (see Figure 4) to be coated is placed several centimeters away from the tips of capillary needles 11 with a metal ground plane 31 placed behind the substrate 30. The substrate 30 is also usually charged with the opposite polarity to that of the capillary needles.

A single needle 11 of the coating head 10 is shown in Figure 4. Each needle 11 is used to produce an ultra-fine mist of droplets. The capillary needle 11 is supplied with the material to be coated from the manifold 15 at a low flow rate and is placed in proximity to the extractor plate 14 with radial symmetry to the hole 13 in the extractor plate 14. An electrical potential V_1 applied between the capillary needle 11 and the extractor plate 14 provides a radially symmetrical electric field between the two. The liquid is electrically stressed by this electric field first into a cone 34 at the very end of the capillary needle and then into a fine filament 35. This filament 35 is typically one or two orders of magnitude smaller than the capillary diameter. Rayleigh jet breakup of this fine liquid filament occurs and causes a fine mist 36 of highly charged ultra-fine droplets to be produced.

These droplets can be further reduced in size if evaporation of solvent from the droplet occurs. When this happens it is believed the charge on the droplet will at some point exceed the Rayleigh charge limit and the droplet will disrupt into several highly charged, but stable smaller droplets. Each of these droplets undergoes further evaporation until the Rayleigh charge limit is again reached and disruption again occurs. Through a succession of several disruptions, solute droplets as small as 500 angstroms in diameter can be produced.

The ultra-fine droplets can be controlled and directed by electric fields to strike the surface of substrate 30 positioned over the ground plane 31. A spreading of the drops occurs on the surface of the substrate and the surface coating is produced. Figure 4 also shows the electrical circuit for the electrospray process. The polarities shown in Figure 4 from the illustrated battery are commonly used, however, these polarities can be reversed. As illustrated, the positive polarity is applied to the capillary needle 11. A negative polarity is attached to the extractor plate 14.

Voltage V_1 is produced between the needle 11 and extractor plate 14 by a high voltage supply and is adjusted to create the desired electric field, E_1, between the capillary tip and extractor plate. This electric field E_1 is dependent on the geometry of the capillary needle and extractor plate.

The mist 36 to be created is dependent upon the fluid and electrical properties of the solution in conjunction with electric field E_1. Fine control of E_1, and thus the mist, can be obtained by varying the capillary tip position with respect to the plane of the extractor plate 14 or by varying the voltage V_1. Although the capillary tip of needle 11 can be located within about 2 cm of either side of the plane of the extractor plate, the preferred position is with the needle extending through the extractor plate 14 from 0.5 to 1.5 cm. The voltage to obtain this field E_1 for the geometry herein described ranges from 3 KV dc to 10 KV dc and is typically between 4 KV dc and 8 KV dc. An alternating current may be imposed on the circuit between the needle and the extractor plate for purposes of producing a frequency modulated to stabilize the creation of monosized droplets.

The substrate to be coated is charged as described hereinafter and a voltage V_2 results, the magnitude of which is a function of the charge per unit area on the substrate 30, the substrate thickness and its dielectric constant. When the substrate 30 to be coated is conductive and at ground potential the voltage V_2 is zero. Discrete conductive substrates, such as a metal disc, placed on an insulated carrier web, can be charged and would have an impressed voltage V_2. An electric field E_2 generated between the capillary tip of the needle 11 and the substrate 30 is a function of V_1 and V_2 and the distance between the capillary tip and the substrate. To insure placement of all the mist droplets on the substrate it is necessary that the potential V_2 never obtains the same polarity as potential V_1. Although coatings are possible when these polarities are the same, coating thickness cannot be assured since some droplets are repelled from the substrate and therefore process control is lost. The distance between the capillary tip and the substrate is determined experimentally. If the distance is too small, the mist doesn't expand properly and if the distance is too great the field E_2 is weak and control is lost in directing the droplets to the substrate. The typical distance for the geometry herein described is between 5 cm and 15 cm. Plates positioned perpendicular to the extractor plate and extending in the direction of movement of the substrate help guide the droplets to the substrate.

In the electrospray process electric field E_1 is the primary field controlling the generation of the fine mist. Electric field E_2 is used to direct the droplets to the substrate where they lose their charge and spread to form the desired coating. Because the droplets tend to repel each other, thin paths through the coating of the first row of needles appear and the staggered position of the needles in the second row of needles in relationship to the path of the web will produce droplets which will coat the paths left by the first row of needles.

Referring now to Figure 3, where the coating process is shown schematically, a roll 40 of substrate 30 to be treated is optionally passed through a corona treater 41 where an electrical discharge precleans the substrate 30. The corona treater 41 may also excite or activate the molecules of the cleaned surface. This can raise the surface energy of the substrate and enhance the wetting and spreading of droplets deposited on the surface. Other methods of cleaning or using a fresh substrete would, of course, be within the spirit of the precleaning step.

If the substrate is nonconductive, a charge, opposite in polarity from the droplet spray, is then placed on the substrate, as for example, by a corona wire 43. Of course, other methods, including ion beams, ionized forced air, etc., could also be used in the charging step. The megnitude of the charge pleced on the surfece is monitored using an electrostatic voltmeter 45 or other suitable means. If the substrate is conductive, this charging step is produced by connecting the substrate to ground.

The liquid to be electrosprayed is provided at a predetermined volume flow rete through a group of capillary needles 11 at the electrospray head 10 such as shown in Figure 1. The electric field E_2 forces the fine droplets of electrospray mist 36 down to the surface of the substrate 30 where charge neutralization occurs as the droplets contact the substrate and spread. If the substrate is nonconductive the charge neutralization reduces the net charge on the substrate and this reduction is measured with an electrostatic voltmeter 47. For accurate coatings, the voltage measured at 47 must be of the same polarity as the voltage measured at 45. This assures a reasonably strong electric field terminates on the substrete, thus effording a high degree of process control.

Under most conditions it is advantageous to neutralize the charge on the substrate after coating. This neutralization step can be accomplished by methods well known in the coating art. A typical neutralizing head 48 may be a Model 641-ESE 3M® Electrical Static Eliminetor obtainable from Minnesota Mining and Manufacturing Company of St. Paul, Minnesota. The coating meterial is then cured by e method suitable for the coating material and such curing device is depicted at 49 and the coeted substrate is rewound in a roll 50. A typical curing device mey be a UV lamp, an electron beam or a thermal heater.

A second embodiment of the coating head is illustrated in Figure 5 and comprises two longitudinal rows of capillary needles 11 secured to a stainless steel plate 60 to communicate with a reservoir 15. The reservoir is formed by a gasket 61 positioned between the plate 60 end a second plate 62 having an opening communicating with a supply line 16 leading from a pump supplying the coating material.

The needles 11 extend through openings 13 in an extractor plete 14. A sheet of plastic material 64 is positioned above the upper planar surface of the extractor plate 14 with an opening 65 to receive the needle 11. A second sheet 66 is positioned adjacent the opposite planar surfece of the plate 14 and covers the planar edges. The sheet 66 has a countersunk hole 68 formed therein and aligned with each hole 13 to restrict the movement of any droplets toward the extractor plate 14 under the electrostatic forces produced between the extractor plate 14 end the needles 11. The extractor plate 14 and sheets 64 and 66 are supported from the conductive plate 60 by insulative spacers 70 and 71. A plate 72 provides support for the head and is joined to the coating head by insulative braces 73.

The solution to be electrosprayed must have certain physical properties to optimize the process. The electrical conductivity should be between 10^{-7} and 10^{-3} siemens per meter. If the electrical conductivity is much greater than 10^{-3} siemens per meter, the liquid flow rate in the electrospray becomes too low to be of practical value. If the electrical conductivity is much less than 10^{-7} siemens per meter, liquid flow rate becomes so high that thick film coatings result.

The surface tension of the liquid to be electrosprayed (if in air et atmospheric pressure) should be below about 65 millinewtons per meter and preferably below 50 millinewtons per meter. If the surfece tension is too high a corona will occur around the eir at the capillary tip. This will cause a loss of electrospray control and can cause an electrical spark. The use of a gas different from air will change the allowed maximum surfece tension according to the breakdown strength of the ges. Likewise, a pressure change from etmospheric pressure and the use of an inert gas to prevent a reaction of the droplets on the way to the substrete is possible. This can be accomplished by plecing the electrosprey generator in e chamber and the curing station could also be disposed in this chamber. A reactive gas may be used to cause a desired reaction with the liquid filament or droplets.

The viscosity of the liquid must be below a few thousand centipoise, and preferably below a few hundred centipoise. If the viscosity is too high, the filament 35 will not break up into uniform droplets.

The electrospray process of the present invention has many advantages over the prior ert. Beceuse the coatings can be put on using little or no solvent, there is no need for large drying ovens and their expense, and there are less pollution and environmental problems. Indeed in the present invention, the droplets are so small that most if not all of the solvent present evaporates before the droplets strike the substrate. This small use of solvent means there is rapid drying of the coeting and thus multiple coatings in a single process line have been obtained. Porous substrates can be advantageously coeted on one side only because there is little or no solvent available to penetrate to the opposite side.

This is a noncontacting coating process with good control of the uniform coating thickness and can be used on any conductive or nonconductive substrate. There are no problems with temperature sensitive materials as the process is carried out at room temperature. Of course if higher or lower temperatures are required, the process conditions can be changed to achieve the desired coatings. This process can coat low viscosity liquids, so monomers or oligomers can be coated and then polymerized in place on the substrete. The process can also be used to coat through a mask leaving a pattern of coated material on the substrate. Likewise, the

substrate can be charged in a pattern and the electrospray mist will preferentially coat the charged areas.

The following examples illustrate the use of the electrospray process to coat various materials at thickness ranging from a few tens of angstroms to a few thousand angstroms (Å).

Example 1

This example describes the use of the electrospray coating process to deposit a very low coating thickness of primer. The solution to be coated was prepared by mixing 80 ml of Cross-linker CX-100® polyfunctional aziridine crosslinker from Polyvinyl Chemical Industries, Wilmington, Mass. 01887, with 20 ml of water. This material was introduced into a coating head which contained only 21 capillary needles using a Sage® Model 355 syringe pump available from Sage Instruments of Cambridge, Massachusetts. A high voltage (V_1) of 3.4 to 3.8 KV dc was applied between the capillary needles 11 and the extractor plate 14.

A 25.4 cm wide 0.2 mm poly(ethyleneterepthalate) (PET) film was introduced into the transport mechanism. The electrospray extractor plate, held at ground potential, was spaced approximately 6 cm from the film surface. The capillary tip to extractor plate distance was 1.2 cm.

The film was charged under the Corona charger to a potential of approximately - 4.6 KV. The web speed was held fixed at 23 m/min and the volume flow rate per orifice and high voltage potential on the spray head were varied to give the final primer coatings shown as follows:

Head potential (V_1) +(KV)	Per orifice volume flow rate (ul/hr)	Coating thickness Å
3.8	104	50
3.8	89	43
3.4	85	41
3.4	73	35

Coating thicknesses were calculated from first principles. These thicknesses are too small to measure but standard. tape peel tests in both the cross web and down web directions after thermal curing showed an increased peel force, proving the primer material was present.

Example 2

The object of this example is to show the production of a release liner for adhesive products using a low adhesion backsize (LAB) coating. A first mixture of perfluoropolyether-diacrylate (PPE-DA) was prepared as described in U.S. patent No. 3,810,874. The coating solution was prepared by mixing 7.5 ml of PPE-DA, 70 ml of Freon® 113 from E. I. Du Pont de Nemours of Wilmington, Delaware, 21 ml of isopropyl alcohol and 1.5 ml of distilled water. This material. was introduced into the 27 needle coating head using a Sage® model 355 syringe pump to provide a constant flow rate of material. A high voltage V_1 of -5.9 KV dc was applied between the capillary needles and the extractor plate.

A 30.5 cm wide 0.07 mm PET corona pre-cleaned film was introduced into the transport mechanism. The electrospray extractor plate, held at ground potential, was spaced approximately 6 cm from the film surface. The capillary tip to extractor plate distance was 0.8 cm.

The film passed under the Corona charger and the surface was charged to a potential of approximately +5 KV. The web transport speed was fixed at 12.2 m/min and the volume flow rate per orifice was varied giving the final LAB uncured coating thicknesses shown:

per orifice volume flow rate (ul/hr)	Coating thickness Å
2200	200
4400	400
6600	600
8800	800
11000	1000

Coating thicknesses were calculated from first principles and then verified to be within 10% by a transesterification analysis similar to the description in Handbook of Analytical Derivatization Reactions, John Wiley and Sons, (1979), page 166.

Example 3

This example shows the use of the electrospray process for coating lubricants on films. A first mixture consisting of a 3:1 weight ratio of hexadecyl stearate and oleic acid was prepared. The coating solution was prepared by mixing 65 ml of the above solution with 34 ml of acetone and 1 ml of water. This material was introduced into the 27 needle coating head using a Sage® Model 355 syringe pump. A high voltage of -9.5 KV dc was applied between the capillary needles and the grounded extractor plate.

Strips of material to be later used for magnetic floppy discs were taped on a 30 cm wide, 0.07 mm PET transport web. The extractor plate was spaced approximately 10 cm from the film surface. The capillary tip to extractor plate distance was 1.2 cm.

The surface of the strips were charged under the Corona charger to a potential of approximately +0.9 KV. The web transport speed and the volume flow rate per orifice were varied to give the final lubricant coating thicknesses shown as follows:

Web speed (m/min)	per orifice volume flow rate (ul/hr)	Coating thickness Å
16.7	1747	1000
12.2	2541	2000
12:2	3811	3000
10.1	3811	3650

Coating thicknesses were calculated from first principles and verified to be within 15% by standard solvent extraction techniques.

Example 4

This example describes the use of the electrospray coating process to deposit a very low coating thickness of primer on a film in an industrial setting. The solution to be coated was prepared as a mixture of 70 volume % Cross-linker CX-100® from Polyvinyl Chemical Industries, and 30 volume % isopropyl alcohol. This solution was introduced into a 62 capillary needle spray head using a Micropump® from Micropump Corporation, Concord, California. A voltage of +9 KV dc was applied between the capillary needles and the extractor plate. The extractor plate was covered with a 0.95 cm thick layer of Lexan® plastic as available from General Electric Company of Schenectady, New York, as shown in Figure 5, instead of the aforementioned 0.2 mm layer of Scotch Brand® 5481 film tape.

A 96.5 cm wide 0.11 mm PET film was introduced into the transport mechanism. The electrospray extractor plate, held at ground potential, was spaced approximately 6.8 cm from the film surface. The capillary tip to extractor plate distance was 1.1 cm.

The film passed under the corona charger and the surface was charged to a potential of approximately -10Kv.

The film speed was held constant at 98.5 m/min. and the solution flow rate was held at 1300 ul/orifice/hr. The calculated coating thickness of primer was 100Å.

Claims

1. An electrospray head for producing a small particle discharge comprising a capillary needle and a surrounding surface, both at least semiconductive, between which a potential may be may be placed to produce an atomising of liquid at the needle orifice characterized in that a conductive plate (21) supports a plurality of capillary needles (11) arranged in at least two rows with the tips of said needles being in the same plane, and a conductive extractor plate (14) having a plurality of circular holes (13) is positioned with one said needle (11) positioned coaxially with each hole (13) and the extractor plate (14) is spaced a predetermined distance from said conductive plate (21) to develop a uniform mist discharge of fluid from the needles (11), a manifold means (15), communicating with said capillary needles (11), supplies liquid to said rows of capillary needles (13), and electrical means (V_1) develop an electrical potential between each said capillary needle (13) and said extractor plate (14) for applying a thin coating to a web.

2. An electrospray coating head according to claim 1 characterized in that said plurality of capillary needles (13) includes more than twenty needles disposed in two parallel rows with the needles (13) staggered in transverse spacial relationship in the rows.

3. An electrospray coating head according to claim 1, characterized in that an insulating layer (64, 66) is disposed on said extractor plate on the planar surfaces thereof to restrict droplets from collecting on the extractor plate (14).

4. An electrospray coating head according to claim 3 characterized in that said insulating layer (64, 66) is an insulative pressure sensitive adhesive tape.

5. An electrospray coating head according to claim 3 characterized in that said insulating layer (64, 66) is a thin sheet of insulative plastic sheet material.

6. An electrospray coating head according to claim 1 characterized in that said needles are covered by an insulative covering.

7. A process for coating a surface by droplets of a coating material to form a thin coating comprising the steps of pumping the coating material to a capillary needle, creating an electrostatic force between the needle and a surrounding extractor plate to generate a spray of droplets, characterized in that a web is coated, which web has sufficient surface energy to allow a wetting of its surface by small droplets and a plurality of needles in at least two rows are positioned transverse to the web and the process includes the steps of advancing a said web having sufficient surface energy transversely of said rows of capillary needles, creating a second electrical potential between said needles and said web surface to attract charged droplets of material to said surface, and discharging said surface of said substrate.

8. A process according to claim 7 characterized in that the process includes the step of pumping said material to said needles at volumes of between 70 and 11000 ul/hr per needle to produce a coating of material with a thickness less than 5000 Angstroms.

9. A process according to claim 7 or 8 characterized in that the process includes the steps of charging said web to develop an electrostatic field, and said advancing step includes passing the web past at least two rows of capillary needles which are staggered and spaced from the path of said substrate.

10. A process according to claim 9 characterized in that said coating material is one of an oligomer or monomer.

11. A process according to claim 9 characterized in that said process includes the step of curing the coating.

12. A process according to claim 9 characterized in that it includes the step of cleaning said substrate prior to charging said substrate.

13. A process according to claim 9 characterized in that said charging step comprises placing a charge on one surface of a substrate where said coating is desired.

14. A process according to claim 9 characterized in that said charging step comprises connecting the substrate to a ground plane.

15. A process according to claim 9 characterized in that said process includes the step of placing said substrate in an area with air at atmospheric pressure.

16. A process according to claim 9 characterized in that said process includes the step of placing said substrate in the presence of a gas other than air.

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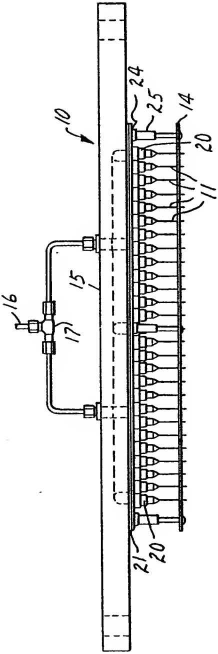

FIG. 1

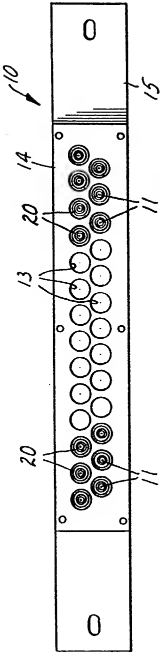

FIG. 2

0258016

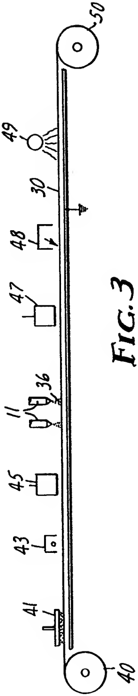

FIG. 3

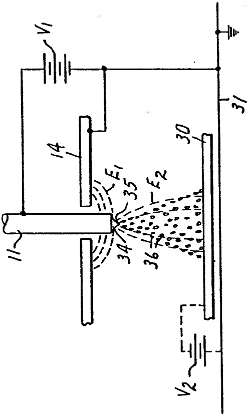

FIG. 4

0258016

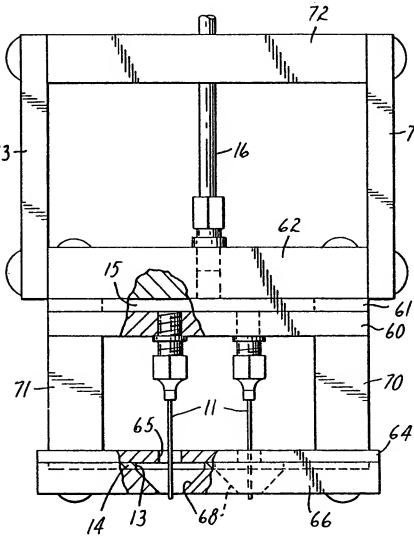

FIG. 5

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 87307432.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	EP - A1 - 0 134 951 (BAYER AG) * Abstract; fig. * --	1,7	B 05 B 5/08 B 05 D 1/04
D,A	US - A - 4 381 342 (VAN HEYNINGEN) * Abstract; fig. 3 * --	1,7	
D,A	US - A - 4 476 515 (COFFEE) * Abstract * --	1,7	
D,A	US - A - 4 209 696 (FITE) * Abstract * ----	1,7	

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

B 05 B
B 05 D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	19-11-1987	SCHÜTZ

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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